# MUNICIPAL WASTEWATER TREATMENT USING CONSTRUCTRED WETLAND: REMOVAL OF CHEMICAL OXYGEN DEMAND (COD) AND TOTAL SUSPENDED SOLID (TSS)

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## ABSTRACT

The lab-scale of surface flow constructed wetland (SF) was applied to treat municipal wastewater for removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). The aim of this study was to determine the percentage removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) at different concentration of wastewater and at different number of treatment cycle by using constructed wetland treatment system. Two different concentration of wastewater were used which is diluted wastewater and non diluted wastewater and the treatment system was run for 10 days of treatment. The sample also treated with one treatment cycle and two treatment cycles. For the purpose of this study, the treatment system consists of 4 stages of treatment and it took 10 days to complete one cycle treatment, while for two cycle treatment it took 20 days. The $1^{st}$ and $3^{rd}$ stage is treated by gravel, while $2^{nd}$ and $4^{th}$ stage is treated by *Pistia stratioes*. From result obtained, it shows that treatment system with diluted wastewater by two treatment cycle was more efficient and gave the highest percentage removal of COD (92.5%) and TSS (91.4%), while DO level increased by 120%. Hence, the removal of COD and TSS complied with the requirement of the sewage effluents standard. Results from this study indicate that the Surface Flow Constructed Wetland is suitable and can be develops as one of the technology treatment system in the future.

# ABSTRAK

Satu kajian berskala makmal bagi Tanah Bencah Beraliran Permukaan telah dijalankan untuk merawat sisa air kumbahan setempat bagi penyingkiran Keperluan Kimia Oksigen (COD) dan Pepejal Terampai (TSS). Tujuan kajian adalah untuk melihat peratusan penyingkiran Keperluan Kimia Oksigen (COD) dan Pepejal Terampai (TSS) bagi sisa air kumbahan setempat pada kepekatan yang berbeza dan pada bilangan kitaran rawatan yang berbeza dengan menggunakan Sistem Rawatan Tanah Bencah. Dua kepekatan sisa air kumbahan setempat yang telah digunakan ialah sisa air kumbahan yang telah dicairkan dan sisa air kumbahan tanpa pencairan. Sistem rawatan telah dijalankan selama 10 hari rawatan. Sisa air kumbahan setempat itu juga dirawat pada kitaran yang berbeza iaitu dengan satu kitaran rawatan dan dua kitaran rawatan. Dalam kajian ini, satu kitaran rawatan tersebut terdiri daripada 4 aras dimana ia mengambil masa selama 10 hari untuk melengkapkan satu kitaran rawatan, manakala untuk dua kitaran ia mengambil masa selama 20 hari. Aras 1 dan aras 3 adalah rawatan dengan menggunakan batu kelikir, manakala aras 2 dan 4 rawatan dengan menggunakan *Pistia stratiotes.* Hasil kajian mendapati, sistem rawatan dengan menggunakan sisa air kumbahan setempat yang dicairkan dengan dua kitaran rawatan memberi peratusan penyingkiran Keperluan Kimia Oksigen (COD) yang tertinggi iaitu 92.5% dan penyinggkiran Pepejal Terampai (TSS) sebanyak 91.4% selain peningkatan oksigen terlarut (DO) sebanyak 120%. Keputusan kajian ini juga mematuhi had piawaian pembuangan sisa air kumbahan setempat yang telah ditetapkan. Kesimpulannya, Tanah Bencah Beraliran Permukaan adalah amat praktikal untuk digunakan sebagai salah satu kaedah sistem rawatan bagi merawat sisa air kumbahan setempat secara semulajadi.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| COD | - | Chemical Oxygen Demand |
| TSS | - | Total Suspended Solid |
| BOD | - | Biochemical Oxygen Demand |
| DO | - | Dissolve Oxygen |
| SFCW | - | Surface Flow Constructed Wetland |
| SSFCW | - | Subsurface Flow Constructed Wetland |
| SF | - | Surface Flow |
| SSF | - | Subsurface Flow |
| FWS | - | Free Water Surface |
| SS | - | Suspended Solid |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| $CO_2$ | - | Carbon Dioxide |
| $CH_4$ | - | Methane |
| $N_2$ | - | Nitrogen gas |
| $NH_3$ | - | Ammonia |
| $^oC$ | - | Degree Celsius |
| % | - | Percentage |
| mg/l | - | milligram per liter |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

A constructed wetlands or known as an artificial wetland or wetpark is one of the technology treatment system that have been used internationally and effectively to improve our water quality and to treat various kinds of wastewater. The constructed wetlands act as a biological filter by removing contaminant or pollutants such as heavy metals, organic materials, and also nutrients from the wastewater which involved several physical, chemical and biological process in the transformation and consumption of organic matter within the wetland.

Usually the constructed wetland system consists of three elements which is water or wastewater that needs to be treat, aquatic plants act as a filter or absorber, and also microorganism that can degrade all the contaminant or pollutant in the wastewater. There are several advantages by applying the constructed wetlands system compared to the other conventional treatment. It is very economically and cost effectively, simple and easy to operate, and no complex technology is needed.

In designing the good wetland, the main biological component in the constructed wetland is the aquatic plants (macrophyte). However, it is important in determining the appropriate macrophyte species that can survive in the wastewater

environment, because only a suitable macrophyte can treat a high concentration of pollutant in the wastewater. Recently, floating aquatic macrophyte systems are much better to use compared to the emergent macrophyte treatment system in term of nutrient uptake efficiency, especially macrophyte that has a large roots system. Several study documented that floating macrophyte such as *Pistia Stratiotes* (water lettuce) and *Eichhornia crassipes* (water hyacinth) have the capability to remove a large amount of pollutant, capability to survive at any wastewater environment and also has the highest growth rate (Sooknah *et al.,* 2004).

The aim of this study is to investigate the effectiveness of applying the constructed wetland treatment system in order to remove the pollutant by using floating aquatic species. In this research study, *Pistia Stratiotes* is preferred to use as a macrophyte in the constructed wetland. It is very economically and environmental friendly to use the constructed wetland system rather than conventional treatment system. The conventional treatment system now uses a chemical reagent and still contributes to pollution when react with certain substance compared to the constructed wetland which are treating the water naturally.

## 1.2 Problem Statement

Wastewater pollution has always been a major problem throughout the world. One of the main sources of the pollution is from municipal wastewater. Usually, municipal wastewater comes from residential area, restaurant, cafeteria, or agricultural effluent. This municipal waste consists of organic and inorganic waste includes food scraps waste oils and detergent. This waste is sometime very toxic to the certain aquatic life.

Basically, municipal wastewater contains high level of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). This high level of Chemical Oxygen Demand (COD) results low Dissolve Oxygen (DO) in water and this can lead to mortality of aquatic live. In addition, suspended solid such as organic and inorganic material can cause dirt and odor to the water.

Usually, municipal wastewater will undergo pretreatment before it will discharge into the river. The conventional sewage treatment involve physical, chemical and biological process which are very complex process, required highly cost and still contribute to pollution because it use chemical reagent to treat the wastewater. This conventional treatment system is not environmental friendly.

At the same time, some premise such as restaurant or cafeteria are preferred to discharge all their waste directly into the drain or river without any pretreatment. That waste usually contains mixture of waste oil, waste powder, chemical reagent such as detergent and many more. As a result, this waste can cause water pollution and can affect our water quality after it enters the waterway. Beside that, this wastewater also can cause odor or bad smell to our environment.

In this research study, an alternative method is suggested by using the constructed wetland system for treating the municipal wastewater. This constructed wetland system also has a potential to be developed as one of the wastewater treatment technology. This is because the constructed wetland system provides various advantages which are cost effectively, where it is easy to operate and environmental friendly to other wildlife and ecosystem.

## 1.3 Scope of Research Work

In this experiment, the parameters that are considered are Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). The treatment system consists of 4 stages of treatment and vegetated with *Pistia Stratiotes.*

The scopes of the study are:

i. To investigate the removal efficiency of COD and TSS in treatment system by using different concentration of wastewater.

ii. To investigate the removal efficiency of COD and TSS in treatment system by varies the number of treatment cycle.

iii. To determine the Dissolve Oxygen (DO) level in the wastewater.

## 1.4 Objectives of Study

The objectives of the study are to determine the percentage removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) in municipal wastewater and to determine the Dissolve Oxygen (DO) level in the municipal wastewater.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Wetland

Wetland is an area consisting of soil, plant and water where the soil is covered by water or saturated with moisture such as marsh, swamp or bog. Wetland are defined as land where the water surface is near the ground surface for long enough each year to maintain saturated soil conditions, along with the related vegetation (Sherwood *et al.,* 1995). The Convention of International Importance (The Ramsar Convention 1971) again define wetland as; “Land inundated with temporary or permanent water that is usually slow moving or stationary, shallow fresh brackish or saline where the inundation determine the type and productivity of soils and plant and animals communities”. Generally wetland can be categorized into two, which is natural wetland and constructed wetland.

### 2.1.1 Natural Wetland

Natural wetland is a naturally occurring wetland and variously called swamp, marshes, bog, and pond and it is usually characterized by their plant type, water and geographic condition (Sherwood *et al.,* 1995).

### 2.1.2 Constructed Wetland

Constructed wetland is an opposite of natural wetland where it is define as engineer-made equivalent of natural wetlands, and designed to reproduce and intensify the wastewater treatment processes that occur in natural wetlands (Hammer *et al.,* 1994). They were first introduced to treat wastewater by K.Siedel in 1952 in Germany (Chen *et al.,* 2007). Basically constructed wetland treatment systems consist of four major components which are soil or gravel, water or shallow pond, aquatic plant or macrophyte and also microorganism. . In general constructed wetland has been use to be a good solution to treat the polluted water and restored the ecosystem health (Chen *et al.,* 2007).

#### 2.1.2.1 Constructed Wetland Treatment System

Constructed wetlands system is widely applied for the purification of domestic waste, stormwater runoff, and also industrial effluent. They act as biological filter which involve physical, chemical, and biological reaction which all participate in the reduction of organic, nutrient and microbiological loads (Brix, 1993; Vincent *et al.,* 1994).

Compared to the conventional treatment system, constructed wetland is usually considered to be one of the most promising technologies to treat wastewater due to the low cost operation and construction compared to the traditional one, simple operation and maintenance and also favorable environmental appearance (Buchberger *et al.,* 1995). Constructed wetland also can be operated in different scales and high expenditure for sewage collection systems can be saved.

Although the purpose of constructed wetland is to treat various kind of waste water, it also provides other purposes as well. A well designed constructed wetland has appealing appearance to serve as an artificial landscape and can serve as wildlife habitats and restored the ecosystems health.

### 2.1.2.2 Types of Constructed Wetland

In general, there are two basic designs for the constructed wetland that are commonly used in treatment system; Surface Flow Constructed Wetland (SFCW) and Subsurface Flow Constructed Wetland (SSFCW) (Chen *et al.*, 2007).

Surface Flow Constructed Wetland (SFCW) are the most commonly use and remain primary choice for water treatment. It is also called Free Water Surface Wetland (FWS), because of wastewater flow across on the top of the surface of the bed. Surface Flow Constructed Wetland is shallow, earthen basins planted with rooted, emergent wetland vegetation (National Engineering Handbook, 2002). The wastewater enters at one end of a line excavation and exit at the other end. Figure 2.1 shows the basic concept of Surface Flow Constructed Wetland.

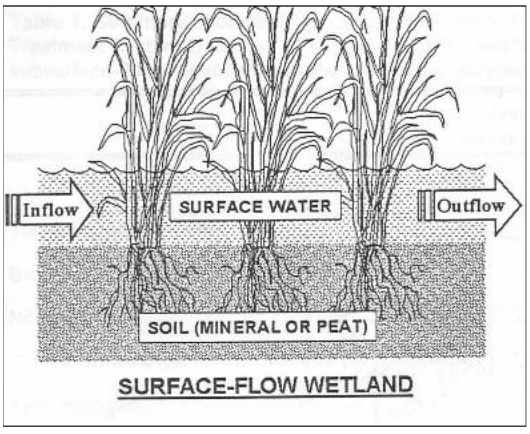



**Figure 2.1:** Basic concept of Surface Flow Constructed Wetland

In Subsurface Flow Constructed Wetland (SSFCW), the water level is maintained below the surface of the bed (gravel) and the effluent move through the medium below the surface, approximately mid-depth. The water level maintained below the surface of the bed can reduces mosquito breeding and fewer odor problems. In this wetland, water enters through an inlet distributor and flows slowly either horizontally or vertically below the ground surface until it reach the outlet of the system (Trevor, 2004). While Subsurface Flow Constructed Wetlands are successfully treating the wastewater, their still appears limited, where the porous bed can be easily plugged with solids and also relatively expensive for most operation (National Engineering Handbook 2002). The basic design for this constructed wetland is shown in Figure 2.2.

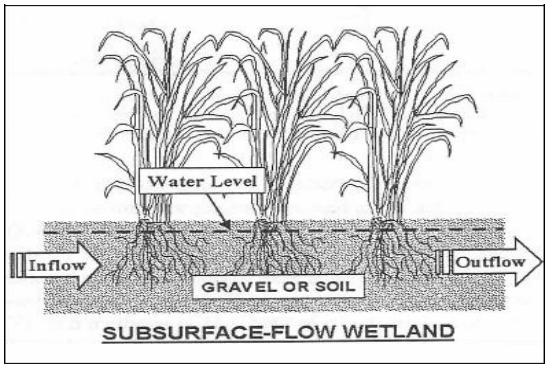



**Figure 2.2:** Basic concept of Subsurface Flow Constructed Wetland

## 2.2 Vegetation (Macrophyte)

Macrophytes or aquatic plant are the conspicuous plants that dominated wetland and normally found growing in association water whose level is at or above the surface of soil. These macrophytes include emergent species, submerged species and floating species (Sherwood *et al.*, 1995).

The role of macrophyte as an essential component of constructed wetland for wastewater treatment is well established (Perkins and Hunter,2000). Macrophytes have a positive effect and capable in enhancing pollutant removal within the system by either assimilating them directly or by providing an environment for surface microbial attachment to transform and uptake pollutant. Beside that, macrophyte can stabilizes the surface of the bed, supply reduces carbon and oxygen in the rhizosphere, decrease current velocity of water, and insulated the surface against frost in winter. (Brisson *et al.,* 2008). Beside, macrophyte can eliminate the disturbing smell of sewage water and reduce inlet odor (Zimmels *et al.,* 2006).

Usually macrophyte that are good tolerance to local condition, have a high growth rate and have flourishing rhizophore system are selected due to their excellent reproduce, ability pollutant removal and also oxygen transportation in the wetland (Chen *et al.,* 2007). In addition, plant species with varying root depth have a greater opportunity of pollutant removal. A basic knowledge about their characteristic in the wetland is essential for successfully treatment wetland (Kadlec, 1996).

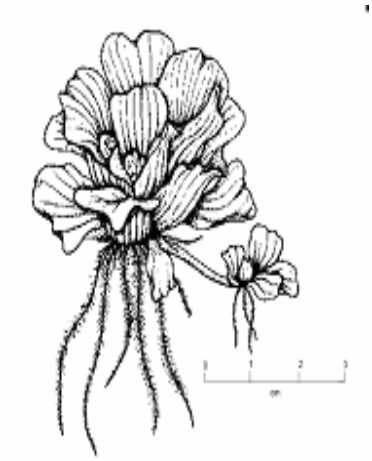
### 2.2.1 Floating Macrophytes

Floating macrophytes are widely used in Surface Flow Constructed wetland and known have a greatest potential for wastewater treatment. This species includes water lettuce (*Pistia stratiotes*), water hyacinths (*E.crassipes*), pennyworth and duckweeds (*Lemna sp*). This plant can survive and grow in anaerobic condition because oxygen is transmitted from the leaves to the root mass. Floating macrophyte such as water hyacinths are capable of removing high level of biological oxygen demand (BOD), suspended solid (SS), metal, nitrogen and other organic materials (Sherwood *et al.,* 1995). The principal removal mechanisms are physical sedimentation and bacterial metabolic activity (USEPA, 1993).

### 2.2.2 *Pistia stratiotes* (Water lettuce)

*Pistia* is a genus of aquatic plant in the family Araceae, comprising single species, *Pistia stratiotes* often called water lettuce. It is a free-floating plant with many spongy, dusty green simple leaves and its root hanging submerged beneath floating leaves. The leaves are covered in very fine hairs and arranged in a spiral pattern from the center of the plant (Wikipedia, 2009). Submerged portions of *Pistia stratiotes* provide habitat for many micro and macro invertebrate. *Pistia stratiotes* also easily to grow and the growth habit can form thick floating mats on the surface of water. If these mats cover the entire surface of the pond they can cause oxygen depletion in the water and killing fish (Rivers, 2002). Table 2.1 summarized the ecological and characteristic of *Pistia stratiotes*.

**Table 2.1:** Ecological and characteristic of *Pistia stratiotes*

| | | |
|---|---|---|
|  *Pistia stratiotes* (Water Lettuce) | **Scientific Classification** | |
| | **Kingdom** | Plantae |
| | **Order** | Alismatales |
| | **Family** | Araceae |
| | **Genus** | *Pistia* |
| | **Species** | *P. stratiotes* |
| | **Characteristic** | |
| | **Roots** | Roots hanging submersed beneath floating leaves, feathery and hairy. |
| | **Leaves** | Thick soft leaves are form in rosettes, parallel ridges (vein), with no leave steam. |
| | **Habitat** | Growth in swamp area, river or pond.<br>Minimum growth temperature: 15$^{o}$C.<br>Optimum growth temperature: 22-30$^{o}$C.<br>Maximum growth temperature: 35$^{o}$C. |

## 2.3 Removal Mechanism in Constructed Wetland

To provide contaminant removal in a constructed wetland, it involves physical, biological and chemical process that operate concurrently as shown in Figure 2.3.

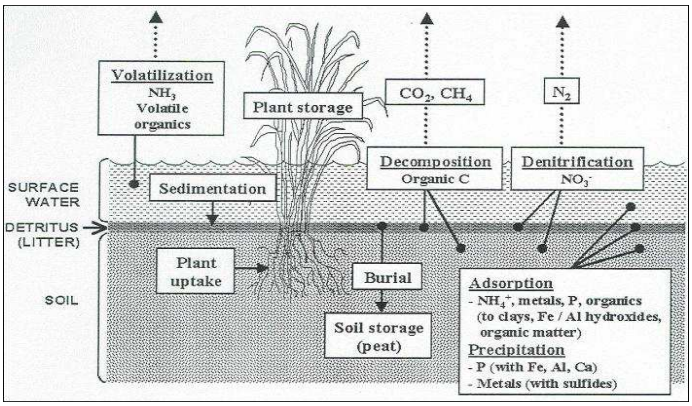



**Figure 2.3:** Summary of contaminant removal in wetland (DeBusk, 1999).

### 2.3.1 Physical Removal

The physical removal in constructed wetland involved of the sedimentation of suspended solid. In constructed wetland, typically the surface water moves very slowly, often laminar flow through wetland due to the resistance provided by root and floating plant and this flow promoted to the sedimentation of the suspended solid in the wetland (DeBusk, 1999). In addition, the present of gravel filtered mostly of the suspended solid and provide opportunities for TSS separation by gravity sedimentation (El-Khatib and El Gohary, 2003)

### 2.3.2 Biological Removal

Biological removal is the most important for contaminant removal in wetlands and this recognized by plant uptake. Contaminant such as nitrate, ammonium, phosphate, and certain toxic such as cadmium and lead are readily taken up by wetland plants. The rate of contaminant removal by plants depends on the plant growth rate and concentration of the contaminant in plant tissue. Algae and bacteria may also provide a significant amount of nutrient uptake but susceptible to the toxic effects of heavy metals. Microbial decomposer utilized the carbon, in organic matter as a source of energy and converting it to carbon dioxide $CO_2$, or methane $CH_4$ gasses. Microbial metabolism also provides removal of inorganic compound such as nitrate and ammonium in wetland and convert nitrate into nitrogen gasses $N_2$ and released to the atmosphere. This process calls denitrification (Debusk, 1999).

### 2.3.3 Chemical Removal

The most important chemical removal in wetland soils is sorption. Sorption is defined term for the transfer of ions from the solution phase (water) to the solid phase (soil). Adsorption refers to the attachment of ions to soil particles. Phosphate can also precipitate with iron and aluminum oxide to form new mineral compound (ferum and aluminum phosphate) which are potentially stable in the soil. Ammonia, $NH_3$ and many types of organic compound are volatile and are readily lost to the atmosphere from wetlands (William, 1999).

## 2.4 Operation and Maintenance in Constructed Wetland

Proper operation and maintenance will ensure that constructed wetlands operate as designed and that the objectives are achieved over the life of the system. Maintenance may be needed to control the spread of undesired plant species and also to remove the debris that will blocked the inlet and outlet flow in the wetland (William, 1995). Special requirements for the constructed wetland include harvesting of the vegetation and mosquito controls. Routine harvesting of vegetation may increase nutrient removal and prevent the dying plants falling in the water (California Stormwater BMP Handbook, 2003). One of the best ways to reduce the mosquito breeding is by introducing the mosquito fish in the wetland such as *Gambusia* fish and also bacteria insecticides such as *Bacillus thuringienss israeliensis* (Robert *et al.*, 2003). To control the spreading of *Pistia*, mechanical harvesters and aquatic herbicides may also be used. Beside, insect are also being use to manage *pistia* such as *Neohydronomous affinis* (Wikipedia, 2009)

## 2.5 Municipal Wastewater

Generally, municipal wastewater that is collected using sewer system can be categorized into two primary types which are general wastewater and stormwater (Timothy, 2003). The characteristics of wastewater discharges will vary from location to location depending on population, land uses and ground water levels.

General wastewater is generated from resident homes, businesses, and industry includes typical waste from toilets, sinks, shower, laundry and so forth as well as any other wastes that people intentionally pour down the drain. Basically general wastewater contains biological, chemical, and physical contaminant that should be reduce prior to discharge to environment. Industrial waste may contained

other contaminants such as metal, detergent, acid and base and therefore require pretreatment prior to discharge into environment (Timothy, 2003).

Stormwater is generated primarily from precipitation runoff from streets, parking lots and other surface. Basically stormwater are much more diluted than general wastewater. Roads and parking lots are subjected to spills of oil, gasoline, and other toxic fluids from automobile, as well as road salt. This contaminant can be carried by stormwater runoff into sewer systems and wastewater treatment facility (Timothy, 2003).

## 2.6 Standard Water Quality Measurement

In order to measure the quality of wastewater before it can be discharge to the river, several parameter need to be considered. For the purpose of this study, two parameter are considered; Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS).

Chemical Oxygen Demand is a measure of oxygen requirement of a sample that is susceptible to oxidation by strong chemical oxidant. Chemical Oxygen Demand test is used to indirectly measure the amount of organic compound in water, while Total Suspended Solid (TSS) is a measured of small solid particles which remain in suspension in water as a colloid and it is used as one indicator of water quality.

Table 2.2 shows the maximum level for this parameter according to the Environmental Protection Agency, EPA. The Environmental Quality Act (EQA) 1974 specifies two standards for effluent discharge, effluent that is discharged